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UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

ORIGINAL

August 27, 2004

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

RE: *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television, Television Translator, and Television Booster Stations and to Amend Rules for Digital Class A Television Stations*, MB Dkt. No. 03-185

Dear Ms. Dortch:

Enclosed please find an original and two (2) copies of ex parte letter to Edmond J. Thomas, Chief of the Office of Engineering and Technology, Federal Communications Commission, from Fredrick R. Wentland, Associate Administration, Office of Spectrum Management, National Telecommunications and Information Administration, in the above-referenced proceeding. Please direct any questions you may have to the undersigned.

Respectfully submitted,

Kathy D. Smith
Chief Counsel

enclosures

cc: Edmond J. Thomas, Chief, Office of Engineering and Technology

UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

AUG 27 2004

Mr. Edmond J. Thomas
Chief, Office of Engineering and Technology
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Dear Mr. Thomas:

The National Telecommunications and Information Administration (NTIA) appreciates the opportunity to provide comments in response to the Federal Communications Commission (Commission) Notice of Proposed Rulemaking (NPRM) to establish service rules for digital low power television (LPTV), television (TV) translator, and booster stations.[1] We believe that this proceeding will further the progress of the transition to nationwide digital TV service and is a necessary step to bring this service to rural areas. In this letter we provide comments in response to two specific issues raised in the NPRM: 1) the ability of the Commission's proposed emission mask for LPTV, translator, and booster stations to protect Global Positioning System (GPS) receivers operating in the radionavigation satellite service (RNSS) frequency bands and 2) the protection of radio quiet zones (RQZs) and radio receiving sites.

NTIA analyzed the potential for interference to GPS receiver operations in the 1559-1610 MHz, 1215-1240 MHz, and 1164-1215 MHz frequency bands resulting from emissions generated by ultra high frequency digital LPTV, translator, and booster stations, and particularly the potential interference from LPTV, translator, and booster stations operating on channels that can generate second or third order harmonics that fall within the RNSS frequency bands. NTIA performed an analysis to assess the potential interference impact of the proposed emission masks in the NPRM on aviation, ground-based, and maritime GPS receivers. The results of this analysis are provided in Attachment A. The U.S. GPS Industry Council (GPS IC) performed an analysis examining the potential impact of digital LPTV, translator, and booster station transmitter harmonic emissions on ground-based (enhanced-911 and timing) and aviation GPS receivers.[2]

1. *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television, Television Translator, and Television Booster Stations and to Amend Rules for Digital Class A Television Stations*, Notice of Proposed Rulemaking, MB Docket No. 03-185, 68 Fed. Reg. 55566 (2003) ("NPRM").

2. U.S. GPS Industry Council, Written *Ex Parte* Presentation, MB Docket No. 03-185 (May 20, 2004).

After filing their written *ex parte* presentation in this proceeding, the GPS IC entered into discussions with the National Translator Association (NTA) regarding emissions in the RNSS frequency bands. As a result of these discussions, they reached an agreement to specify a filter attenuation of 85 dB in the RNSS bands from 1164-1610 MHz.[3] This filter attenuation applies only to those digital LPTV, translator, and booster station transmitters with harmonics that fall within this frequency range.[4] The Community Broadcasters Association also filed an *ex parte* presentation supporting the agreement reached by the GPS IC and NTA.[5] These parties proposed that the Commission adopt the following regulatory text in the service rules for digital LPTV, translator, and booster stations:

> *In addition to the harmonic limits set by the emission mask, specific "Out-of-Band" protection must be provided in the frequency ranges corresponding to the GPS bands: L5 (1164-1215 MHz); L2 (1215-1240 MHz); and L1 (1559-1610 MHz). This special requirement applies specifically to digital LPTV and translator stations operating on channels 22-24, 36-38, and 65-69.*
>
> > *1. A type certified transmitter specifically certified for use on one or more of the above channels must include filtering with an attenuation of 85 dB below the passband and this attenuation must be demonstrated as part of the certification application.*
> >
> > *2. For an installation on one of the above channels with a digital transmitter not specifically type certified for the channel a low pass filter or equivalent device rated by its manufacturer to have an attenuation of at least 85 dB below the passband of the operating channel must be installed in a manner that will prevent the harmonic content from reaching the antenna. A description of the low pass filter or equivalent device with the manufacturer's rating or a report of measurements by a qualified individual shall be retained with the station license. Field measurements of the second or third harmonic output of a transmitter so equipped are not required.*

For a digital LPTV, translator, and booster station transmitter operating at a maximum equivalent isotropically radiated power (EIRP) level of 43.9 dBW (15,000 watts), this proposal would result in an EIRP in the GPS frequency bands of -49 dBW/MHz.

We support the Commission adopting regulations that are based on the proposal agreed to by the GPS IC and representatives of the digital LPTV industry. These regulations would protect GPS signals, which are integral to our national security, public safety, homeland security, and a plethora of critical commercial applications.

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3. U.S. GPS Industry Council, *Ex Parte* Presentation in MB Docket No. 03-185, at 2 (July 26, 2004).

4. *Id.*

5. Community Broadcasters Association, *Ex Parte* Letter in MB Docket No. 03-185 (August 5, 2004).

With respect to protection of the RQZs, radio receiving sites, and the Commission's monitoring stations, we support the Commission's proposal that digital LPTV, translators, and booster stations conform to the requirements in Section 73.1030 of its rules.[6] The limits in this section specify the field strength (and equivalent power flux densities) radiated onto these zones, sites, and stations. These limits apply to the total power radiated by a digital LPTV, translator, and booster station, which is the appropriate means of protecting sensitive wideband measurements. Attachment C provides additional justification for the need to protect RQZs, radio receiving sites, and monitoring stations. Given the importance of the measurements performed at facilities such as the Department of Commerce radio receiving facility at Table Mountain, Colorado, we believe that the field strength limits and coordination requirements specified in Section 73.1030 must apply to digital LPTV, translator, and booster stations operating in proximity to these facilities.

We strongly recommend that the Commission adopt the proposals discussed above in the service rules for digital LPTV, translator, and booster stations. If you have any questions about our comments, please feel free to contact me at 202-482-1850.

Sincerely,

Fredrick R. Wentland
Associate Administrator
Office of Spectrum Management

Attachments

6. 47 C.F.R. Section 73.1030.

ATTACHMENT A

ASSESSMENT OF POTENTIAL INTERFERENCE TO GLOBAL POSITIONING SYSTEM RECEIVERS FROM DIGITAL LOW POWER TELEVISION, TRANSLATOR, AND BOOSTER STATIONS

1.0 INTRODUCTION

1.1 Background

The Federal Communications Commission (Commission) released a Notice of Proposed Rulemaking (NPRM) to establish service rules for digital low power television (LPTV), television (TV) translators, and TV booster stations.[1] As part of the service rules in the NPRM the Commission requests public comment on two emission mask proposals for the digital LPTV, translator, and booster stations. The two masks are referred to as the "Simple Mask" and the "Stringent Mask".[2] The analysis used to develop the two emission masks only considered potential interference to other digital LPTV, translator, booster, and full service digital TV (DTV) stations.[3] The analysis did not consider potential interference to other authorized radio services.

Outside of the authorized channel, the Commission's Rules limit undesired emissions of analog television (TV) signals to levels 60 dB below that of the fundamental.[4] However, measurements conducted at numerous TV stations throughout the United States found that in all cases these emission levels were below –100 dB relative to the carrier, which is 40 dB lower than the Commission's specification.[5] Analog TV station operators keep harmonic content low because this substantially improves the quality of the received TV picture. For digital TV signals, the Commission requires that signals that are removed by more than 6 MHz from the channel edge be attenuated to at least 110 dB in a 500 kHz bandwidth relative to the average transmitted power within the authorized channel.[6]

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1. *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television, Television Translator, and Television Booster Stations and to Amend Rules for Digital Class A Television Stations*, Notice of Proposed Rulemaking, MB Docket No. 03-185, 68 Fed. Reg. 55566 (2003) ("NPRM").

2. *Id.* at ¶ 65.

3. The Institute of Electrical and Electronics Engineers Transactions on Broadcasting *DTV Repeater Emission Mask Analysis*, Vol. 49, Number 1, at 32 (March 2003).

4. The fundamental frequency is the principle component of a wave and is normally the assigned frequency of an electromagnetic emission.

5. Elliott D. Kaplan, Editor, *Understanding GPS Principles and Applications*, Artech House Publications, at 226 (1996).

6. 47 C.F.R. Section 73.622(h)(1).

NTIA previously raised a concern with the Commission regarding the potential for interference to Global Positioning System (GPS) receivers as a result of harmonic signals generated by the digital LPTV, translator, and booster stations.[7] The full service DTV stations have already addressed this issue by adopting a mask that limits the levels of these unwanted emissions to –110 dB in a 500 kHz bandwidth relative to the average transmitted power in the authorized channel. Since the effective radiated power (ERP) levels for digital LPTV, translator, and booster stations are less than those allowed for full service DTV stations, the emission masks proposed by the Commission permit higher signal levels relative to the fundamental emission. In the radionavigation satellite service (RNSS) frequency bands, 1563-1587 MHz (L1), 1215-1240 MHz (L2), and 1164-1188 MHz (L5), used by the GPS service, the Simple Mask attenuates emission levels 71 dB in a 500 kHz bandwidth relative to the average transmitted power in the authorized channel. The required attenuation in the RNSS frequency bands for the Stringent Mask is 76 dB.

1.2 Objective

The objective of this analysis is to assess the potential of interference to aviation, ground-based, and maritime GPS receivers operating in the RNSS frequency bands using the proposed emission masks for digital LPTV, translator, and booster stations. Based on the results of the analysis, NTIA determined the unwanted emission levels needed to ensure compatibility.

1.3 Approach

To assess the interference potential of digital LPTV, translator, and booster station emissions to GPS receivers, NTIA performed an analysis to compute the maximum allowable equivalent isotropically radiated power (EIRP) levels of the emissions in the frequency bands used by the GPS service that are necessary for compatible operation. The analysis considers GPS receivers used in aviation, ground-based, and maritime applications. The GPS receiver architecture considered will determine the maximum permissible interference levels. The GPS receiver applications determine the operational scenario considered in the analysis. The computed maximum allowable EIRP levels are compared to the EIRP levels based on the proposed emission masks to determine if additional attenuation is necessary for compatible operation.

2.0 DIGITAL LPTV, TRANSLATOR, AND BOOSTER STATION CHARACTERISTICS

2.1 EIRP Levels

The NPRM proposes two emission masks for digital LPTV, translator, and booster stations. The Simple Mask attenuates emissions in the RNSS frequency bands by 71 dB, whereas the Stringent Mask attenuates the emission levels in the RNSS frequency bands by 76 dB. In this assessment NTIA used the emission level of the Stringent Mask. The proposed transmitter ERP levels for ultra high frequency (UHF) digital LPTV, translator, and booster

7. Letter from Frederick R. Wentland, Associate Administrator, National Telecommunications and Information Administration, Office of Spectrum Management, to Edmond J. Thomas, Chief, Federal Communications Commission, Office of Engineering and Technology (July 30, 2003).

stations are limited to 15,000 watts.[8] The following equation is used to convert from ERP as specified in the Commission's Rules to EIRP, which is used in this analysis:

$$EIRP = 10 \text{ Log } (ERP) + 2.1 \qquad \text{(A-1)}$$

Using Equation A-1 the EIRP level for UHF digital LPTV, translator, and booster stations is:

$$EIRP = 10 \text{ Log } (15000) + 2.1 = 44 \text{ dBW}$$

The EIRP within the allocated channel is measured in a 6 MHz bandwidth. Outside of the allocated channel the emission levels are measured in a 500 kHz bandwidth. Since the maximum permissible emission interference level for the GPS receivers is expressed in terms of a 1 MHz bandwidth, the EIRP level computed using Equation A-1 is adjusted by a factor of 10 Log $(1x10^6/500x10^3)$ = 3 dB. The EIRP level is then adjusted to include the attenuation level of 76 dB corresponding to the Stringent Mask.

The EIRP levels used in this analysis for the UHF digital LPTV, translator, and booster stations are:

$$EIRP = 44 + 3 - 76 = -29 \text{ dBW/MHz}$$

2.2 Antenna Height

The antenna height for the digital LPTV, translator, and booster stations are expressed in terms of height above average terrain (HAAT). In this analysis a HAAT of 100 feet (30 meters) is considered.

2.3 Antenna Vertical Gain Pattern

The vertical antenna gain pattern defined in the Commission's Office of Engineering and Technology Bulletin No. 69 is used in this analysis for the UHF digital LPTV, translator, and booster stations.[9] The antenna gain reduction in the vertical plane as a function of angle is provided in Table A-1.[10] For angles above 0.75 degrees a symmetrical antenna pattern was assumed. For angles greater than 9.25 degrees above and 10 degrees below, the values at 10 degrees were used. Linear interpolation was used to determine the antenna gain reductions between the values provided in Table A-1.

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8. NPRM at ¶ 61.

9. Federal Communications Commission, Office of Engineering and Technology, Bulletin No. 69,*Longley-Rice Methodology for Evaluating TV Coverage and Interference*, at 15 (July 2, 1997).

10. The values shown in Table A-1 are computed by taking 20 Log of the field strength values in Table 8 of OET Bulletin No. 69.

Table A-1.

Angle Below Horizontal (Degrees)	Gain Reduction in Vertical Plane (dB)
0.75	0
1.5	-1.1
2	-3.2
2.5	-6.7
3	-11.7
3.5	-12.6
4	-13.6
5	-13.9
6	-16.5
7	-16.5
8	-16.5
9	-16.5
10	-16.5

3.0 ANALYSIS APPROACH

This section describes the analysis procedures used to determine the maximum allowable EIRP level necessary for compatible operation between the UHF digital LPTV, translator, and booster stations and GPS aviation, ground-based, and maritime receivers.

The maximum allowable EIRP level is determined using the following equation:

$$EIRP_{Max} = I_{Max} - G_T(\theta) - G_R(\theta) + L_P - L_{Safety} \qquad \text{(A-2)}$$

Where:

$EIRP_{Max}$ is the maximum allowable EIRP of the digital LPTV, translator, and booster stations (dBW/MHz);

I_{Max} is the maximum permissible interference level at the GPS receiver input (dBW/MHz);

$G_T(\theta)$ is the reduction in the digital LPTV, translator, and booster station EIRP in the direction of the GPS receiver as a result of the vertical antenna gain (dB);

G_R is the GPS receive antenna gain in the direction of the digital LPTV, translator, and booster stations (dBi);

θ is the vertical angle between the digital LPTV, translator, booster station and the GPS receiver (degrees);

L_P is the propagation loss between the GPS receiver and the digital LPTV, translator, and booster stations (dB);

L_{Safety} is the aviation safety margin (dB).

The value of $EIRP_{Max}$ computed using Equation A-2 is compared to the emission levels proposed by the Commission to determine whether adjustments to the proposed emission mask is necessary to ensure compatible operation with aviation, ground-based, and maritime GPS receivers.

3.1 Maximum Permissible Interference Levels

3.1.1 GPS Receivers

The maximum permissible interference levels used in this analysis will depend on the GPS receiver architecture and application. The GPS receiver architectures considered in this analysis include: coarse/acquisition (C/A) code, assisted-GPS, narrow correlator C/A code, and semicodeless. These GPS receiver architectures are used in aviation, ground-based, and maritime applications.

The maximum permissible interference level of a GPS receiver depends on the receiver architecture and the characterization of the interfering signal. In assessing interference impact to GPS receivers the interfering signals have been characterized as being noise-like, pulse-like, or continuous wave (CW)-like. The potential impact to a C/A code GPS receiver from a CW interfering signal is more detrimental as compared to a noise-like interfering signal. Semi-codeless GPS receivers have the same susceptibility to CW and noise-like interference. The UHF digital LPTV, translator, and booster station signals use digital modulation that appears noise-like within the authorized channel.[11] However, there is a narrowband pilot carrier signal that is located 309.441 kHz from the lower edge of the authorized channel.[12] In this analysis, for establishing the GPS maximum permissible interference level, the emissions generated by the LPTV, translator, and booster station emissions appearing in the GPS frequency bands are treated as being noise-like. The analysis of the potential interference to L1 GPS C/A code receivers from the pilot carrier signal is addressed in Attachment B.

3.1.1.1 Aviation GPS Receivers

The GPS receiver architecture considered in assessing the potential impact to GPS aviation receivers is the narrow correlator C/A code used for precision approach. The narrow correlator receivers operate in the L1 frequency band and are planned for operation in the L5 frequency band.

3.1.1.1.1 Precision Approach. GPS receivers will be used to support precision approach Category I, II, and III capabilities.[13] For in-band broadband noise interference both the RTCA and International Telecommunication Union-Radiocommunications Sector (ITU-R) specify a maximum permissible interference level of -140 dBW/MHz. This level is specified for a GPS L1 narrow correlator C/A code aviation receiver operating in the tracking mode. For a GPS aviation receiver operating in the acquisition mode the RTCA and ITU-R specify a maximum permissible

11. IEEE Analysis at 35. Digital TV employs a single carrier high data rate amplitude modulated suppressed carrier vestigial sideband signal (VSB). There are 8-level and 16-level VSB modes.

12. *Id.* at 34.

13. Category I, II, III landing conditions define the landing visibility conditions in terms of the verticalvisibility ceiling and runway visual ranges. Increasing category numbers means that visibility is decreasing.

interference level of -146 dBW/MHz.[14] GPS receivers used for precision approach will not be acquiring new satellites, thus it is appropriate to use the maximum permissible interference level required to protect the tracking mode of operation.

The maximum permissible interference levels for aviation GPS receivers using the L5 frequency have not been finalized.[15] It is envisioned that a receiver technology will be employed that is comparable in terms of performance (in the presence of noise-like interference) to the GPS receivers used in the L1 band with similar protection requirements. Therefore, in this analysis the RTCA and ITU-R maximum permissible interference levels for the L1 signal are used.

3.1.1.2 Ground-Based GPS Receivers

Three GPS receiver architectures used in ground-based applications are considered in this analysis: C/A code used for most general use applications operating in the L1 frequency band, assisted-GPS[16] used for enhanced-911 (E-911) applications operating in the L1 frequency band, and semicodeless used in surveying applications operating in the L1 and L2 frequency bands.

3.1.1.2.1 General Use. The GPS C/A code receiver makes up a significant share of the GPS receivers in use today for civilian applications. The maximum permissible interference level used in this analysis is based on measurements performed by NTIA on several C/A code receivers operating in the L1 frequency band. The performance metric used in these measurements was break-lock.[17] The interfering signal used in these measurements was broadband noise. The maximum permissible interference level for C/A code receivers used in this analysis is -133.2 dBW/MHz, which is a median value for the combined measured data of the three receivers measured.[18] However, as the new civil signals become available, GPS receivers will be developed that use L2 and L5 frequency bands. Since there is no information on GPS receivers that will use the civil signals to be provided at L2 and L5, the maximum

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14. Document Number RTCA/Do-229B, *Minimum Operational Performance Standard for GPS/Wide Area Augmentation System Airborne Equipment*, at 38 (January 1996); ITU-R Recommendation M.1477, *Technical and Performance Characteristics of Current and Planned RNSS (Space-to-Earth) and ARNS Receivers to be Considered in Interference Studies in the Band 1559-1610 MHz,* at Table 1 ("ITU-R M.1477").

15. RTCA SC 159 Working Group 6 is in the process of developing a Minimum Operational Performance Standard for GPS L5 receivers.

16. Assisted-GPS describes a system where outside sources, such as an assistance server and reference network, help a GPS receiver perform the tasks required to make range measurements and position solutions. The assisted-GPS receivers currently being developed operate in the L1 frequency band. However, as the new civil signals at L2 and L5 becomes operational, assisted-GPS receivers will probably be developed that also operate in these frequency bands.

17. Break-lock refers to the loss of signal lock between the GPS receiver and a GPS satellite.

18. National Telecommunications and Information Administration, NTIA Special Publication 01-47, *Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers (Report Addendum),* at 2-13 (November 2001).

permissible interference level developed for the L1 signal receivers for noise-like interference is used in this analysis.

3.1.1.2.2 E-911. Since ground-based GPS receivers typically operate at their minimum signal levels, any interfering signal that adds to system noise density erodes performance by requiring stronger GPS signals to perform the required function. Conventional C/A code GPS receivers require a relatively high carrier-to-noise density ratio (C/N_0) because of the wide loop bandwidths that are employed. In contrast, GPS receivers using assisted-GPS technology can take full advantage of communications network support to obtain and remove the GPS navigation data and to stabilize the receiver clock. In addition, it is assumed that the dynamics are very low (e.g., the user is walking). As a result, the tracking loop bandwidth can be narrowed substantially, thus maintaining a positive signal-to-noise ratio in the tracking loop at much lower C/N_0 values. Receivers are being sold today that can track with a 20 dB-Hz C/N_0.[19] The typical GPS receiver noise density is -201 dBW/Hz for a receiver with a 3 dB noise figure. A 20 dB-Hz C/N_0 represents a receiver signal level of -181 dBW, which is 21 dB below the GPS minimum guaranteed signal level specified in the Standard Positioning Service Signal Specification. Given these lower signal levels, it is important to limit increases in system noise. There is very little measured data for the maximum permissible interference levels for assisted-GPS receivers. In this analysis, the maximum permissible interference level is based on an increase in system noise of 25%, which equates to an interference-to-noise ratio (I/N) of -6 dB. Based on an I/N = -6 dB, the maximum permissible interference level used in this analysis for assisted-GPS receivers operating in the L1 frequency band is -201 dBW/Hz + 60 – 6 = -147 dBW/MHz. However, as the new civil signals become available, GPS receivers will be developed that use L2 and L5 frequency bands. Since there is no information on assisted-GPS receivers that will use the civil signals to be provided at L2 and L5, the maximum permissible interference level, in the presence of noise-like interference, developed for the L1 signal receivers is used in this analysis.

3.1.1.2.3 Surveying. Semicodeless GPS receivers operating in the L1 and L2 frequency bands are used in low dynamic applications requiring high precision such as surveying. The maximum permissible interference level for this GPS receiver architecture used in this analysis is based on measurements performed by NTIA. The performance metric used in these measurements was break-lock and the interfering signal was broadband noise. The maximum permissible interference level used in this analysis for semi codeless receivers is -145.5 dBW/MHz.[20] This measured value is within 1 dB of the maximum permissible interference level specified by the ITU-R for an SBAS receiver that also employs the semicodeless receiver architecture.

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19. The October 2003 GPS World reported that Motorola has launched an assisted-GPS module for applications in cell phones that achieves a signal detection of -182 dBW.

20. National Telecommunications and Information Administration, NTIA Special Publication 01-45, *Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers,* at 2-4 (February 2001) ("NTIA Special Publication 01-45").

3.1.1.3 Maritime GPS Receivers

Maritime GPS receivers are used for navigation in constricted waterways, harbor navigation, docking operations, navigation around bridges, and lock operations. The International Electrotechnical Commission (IEC) has adopted a maximum permissible interference level based on the levels developed by RTCA for aviation receivers.[21] The level specified is for a GPS L1 narrow correlator C/A code receiver. As the civil signals at L2 and L5 become available, maritime receivers will be built that process these signals. For in-band broadband noise interference, the IEC has specified a maximum permissible interference level of –140 dBW/MHz for a GPS maritime receiver operating in the tracking mode. In this analysis, the maximum permissible interference level for a maritime GPS receiver operating in the tracking mode is used.

3.2 GLONASS and Galileo Receivers

As discussed in RTCA DO-235, the interference protection requirements for GPS and GLONASS are essentially the same.[22] A new RNSS system such as Galileo will probably have similar operating characteristics as GPS, and thus will require the same protection from interference. Based on the continuing evolution of the GNSS, the maximum allowable EIRP levels established in this analysis for UHF digital LPTV, translator, and booster station emissions will apply across the entire 1559-1610 MHz, 1215-1350 MHz, and 1164-1215 MHz RNSS frequency bands.

3.3 Summary of Maximum Permissible Interference Levels

A summary of the maximum permissible interference levels used in this analysis is provided in Table A-2.

Table A-2.

GPS Frequency Band	Receiver Architecture	Receiver Application	Maximum Permissible Interference Level
L1 and L5	Narrow Correlator C/A Code	Precision Approach	-140 dBW/MHz
L1, L2, and L5	C/A Code	General Use	-133.2 dBW/MHz
L1, L2, and L5	Assisted-GPS	E-911	-147 dBW/MHz
L1 and L2	Semicodeless	Surveying	-145.5 dBW/MHz
L1, L2, and L5	Narrow Correlator C/A Code	Maritime	-140 dBW/MHz

21. International Electrotechnical Commission, IEC 61108-1, *Global Navigation Satellite System (GNSS), Part 1: Global Positioning System (GPS) Receiver Equipment Performance Standard, Methods of Testing and Required Results.*

22. Document No. RTCA DO-235, *Assessment of Radio Frequency Interference Relevant to the GNSS,* at F-12 (January 27, 1997) ("DO-235").

4.0 OPERATIONAL SCENARIO DESCRIPTIONS

This section describes the operational scenarios considered in this analysis. The operational scenario development involves determining the separation distance between the UHF digital LPTV, translator, and booster station and the GPS receiver. The separation distance will be different for each of the GPS receiver applications considered in this analysis. The separation distance defines the type of propagation (e.g., free space, multipath). The operational scenario also determines the antenna coupling between the digital LPTV, translator, and booster station and the GPS receiver.

4.1 Aviation GPS Receivers

4.1.1 Precision Approach. In Federal Aviation Administration Order 7400.2D, Part 2, Objects Affecting Navigable Airspace, Figure 4-23, a 50 to 1 obstruction limit is required. Using this obstruction limit the 30 meter digital LPTV, translator, booster antenna considered in this analysis must be located 1500 meters from the runway. For this operational scenario this represents the separation distance.

The NTIA Institute for Telecommunication Sciences Irregular Terrain Model (ITM) is used to compute the propagation loss for this operational scenario.[23] This is the same propagation model used in the OET Bulletin No. 69. For the antenna heights of 30 meters and terrain roughness factors of 10 and 20 meters at the L1 and L5 frequencies, the ITM model predicted free space propagation loss for both 50% of the locations and 90% of the time (50,90) and 50% of the locations and 10% of the time (50,10). The radiowave propagation described by the free space loss model is given by the following equation:

$$L_p = 20 \text{ Log } F + 20 \text{ Log } D_{sep} - 27.55 \qquad \text{(A-3)}$$

Where:

F is the frequency (MHz);

D_{sep} is the separation distance between the digital LPTV, translator, and booster station and the GPS receiver (m).

Using free space propagation model in Equation A-3, the computed values of propagation loss used in this operational scenario are:

$$L_p = 20 \text{ Log } (1575) + 20 \text{ Log } (1500) - 27.55 = 63.9 + 63.5 - 27.55 = 99.9 \text{ dB} \qquad \text{(L1)}$$

$$L_p = 20 \text{ Log } (1176) + 20 \text{ Log } (1500) - 27.55 = 61.4 + 63.5 - 27.55 = 97.4 \text{ dB} \qquad \text{(L5)}$$

23. National Telecommunications and Information, Institute for Telecommunication Sciences, NTIA Report 82100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode* (April 1982).

The GPS receive antenna gain model to be used in this aviation analysis is provided in Table A-3.

Table A-3.

Off-Axis Angle (Measured with Respect to the Horizon)	GPS Antenna Gain (dBi)
-90 degrees to -30 degrees	-10
-30 degrees to 0 degrees	-5

An aircraft at the Category I decision point is 100 feet (30 meters) above any terrain or obstacles. This is the same height as the antenna for the digital LPTV, translator, and booster station considered in this analysis. The GPS receive antenna gain at a 0 degree angle with respect to the horizon from Table A-3 is -5 dBi.

Based on the elevation antenna pattern provided in Table A-1, there will be an antenna gain reduction in the direction of the GPS equipped aircraft at the Category I decision point of -1.1 dB for UHF digital LPTV, translator, and booster stations.

When the operational scenario involves aviation applications using GPS for precision approach, inclusion of a safety margin is appropriate. The aviation safety margin is used to account for uncertainties in the aviation link budget that are real but not quantifiable, which include but are not limited to: multipath of the GPS signal; receiver implementation losses; antenna gain variations; and approach path deviation. Since the GPS signal level cannot be increased, the aviation safety margin is implemented by lowering the allowable interference. A safety margin of 6 dB is included in this analysis. The aviation safety margin included in this analysis is consistent with the value specified in ITU-R Recommendation M.1477.

4.2 Ground-Based GPS Receivers

4.2.1 General Use

The general use GPS receivers considered in this analysis are either hand-held or vehicle mounted. The antenna height of these receivers considered in this analysis is 2 meters. Since these GPS receivers are mobile it is difficult to determine a separation distance. In this analysis, a worst-case horizontal separation distance between the digital LPTV, translator, and booster station is computed based on the point where the coupling loss is a minimum value. The coupling loss is the combination of the propagation loss, antenna gain reduction for the digital LPTV, translator, and booster station, and the GPS receive antenna gain. The propagation loss used in this analysis is computed using Equation A-3. The antenna gain reduction for the digital LPTV, translator, and booster station is provided in Table A-1. The GPS receive antenna gain is given in Table A-4. The vertical antenna angle used to determine the UHF digital LPTV, translator, and booster station antenna gain reduction and the GPS receive antenna gain is computed using Equation A-4.

Table A-4.

Off-Axis Angle (Measured with Respect to the Horizon)	GPS Antenna Gain (dBi)
-90 degrees to –10 degrees	-4.5
-10 degrees to 10 degrees	0
10 degrees to 90 degrees	3

The vertical antenna angle used to determine the digital LPTV, translator, and booster station antenna gain reduction and the GPS receive antenna gain is computed using Equation A-4.

$$\theta = \mathrm{Tan}^{-1}\left[(h_{TV} - h_{GPS})/d_H\right] \qquad \text{(A-4)}$$

Where:

θ is the vertical angle between the transmit and receive antennas (degrees);
h_{TV} is the height of the digital LPTV, translator, booster station (m);
h_{GPS} is the height of the GPS receive antenna (m);
d_H is the horizontal distance between the digital LPTV, translator, booster station and the GPS receive antenna (m).

To determine the distance separation, the difference in the antenna heights of the GPS ground-based receiver and the digital LPTV, translator, booster station tower must be taken into account. The distance separation between a GPS ground-based receiver and a digital LPTV, translator, booster station is based on the slant range. The slant range used to compute the propagation loss is given by Equation A-5:

$$D_{sep} = \left[(h_{TV} - h_{GPS})^2 + (d_H)^2\right]^{0.5} \qquad \text{(A-5)}$$

Where:

h_{TV} is the height of the digital LPTV, translator, booster station tower (m);
h_{GPS} is the height of the GPS receive antenna (m);
d_H is the horizontal distance between the digital LPTV, translator, booster station tower and the GPS receive antenna (m).

Table A-5 summarizes the coupling loss calculations for horizontal distance separations ranging from 200 meters to 1000 meters. For separation distances less than 1 kilometer, ITM defaults to the free space model described in Equation A-3. As shown in Table A-5 the minimum coupling loss occurs for separation distances between 800 and 1000 meters. In this analysis, a separation distance of 1000 meters is used to compute the propagation loss.

Table A-5.

Horizontal Separation Distance (m)	Slant Range(m)	Path Loss (dB)	Vertical Angle (deg)	Reduction in TV Antenna Gain(dB)	GPS Receive Antenna Gain (dBi)	Coupling Loss (dB)
200	202	82.5 (L1) 80.4 (L2) 80 (L5)	7.9	-16.5	0	-99 (L1) -96.9 (L2) -96.5 (L5)
400	401	88.5 (L1) 86.4 (L2) 86 (L5)	4	-13.6	0	-102.1 (L1) -100 (L2) -99.6 (L5)
800	800.5	94.5 (L1) 92.4 (L2) 92 (L5)	2	-3.2	0	-97.7 (L1) -95.6 (L2) -95.2 (L5)
900	900.4	95.5 (L1) 93.4 (L2) 93 (L5)	1.8	-2.4	0	-97.9 (L1) -95.8 (L2) -95.4 (L5)
1000	1000.4	96.4 (L1) 94.3 (L2) 93.9 (L5)	1.6	-1.5	0	-97.9 (L1) -95.8 (L2) -95.4 (L5)

Using free space propagation model in Equation A-3 the computed values of propagation loss used in this operational scenario for a 1000 meter separation distance are shown in Table A-5.

As shown in Table A-5, the reduction in the digital LPTV, translator, booster station antenna gain is –1.5 dB for a separation distance of 1000 meters.

The GPS receive antenna gain for the separation distance of 1000 meters is shown in Table A-5 as 0 dBi.

4.2.2 E-911

When operating in areas where the view to the GPS satellites is unobstructed and the received signal levels are high, the performance of an assisted-GPS receivers is similar to that of a conventional C/A code receiver. Only when the received GPS satellite signal level is degraded due to building blockage or when it is operating indoors, do the assisted-GPS receiver processes lower received signal levels. As discussed earlier, the ability of the assisted-GPS receiver to process these lower received signal levels that makes it more susceptible to increased system noise due to interference.

In this operational scenario, the separation distances of 1000 meters computed for the general use ground-based GPS receiver is used since the geometry can be the same. For separation distances less than 1 kilometer, ITM defaults to the free space propagation model described in Equation A-3. Using the free space propagation model, the computed values of propagation loss used in this operational scenario for the 1000 meter separation distance are shown in Table A-5.

As shown in Table A-5, the reduction in the digital LPTV, translator, booster station antenna gain is –1.5 dB for a separation distance of 1000 meters.

The GPS receive antenna gain for the separation distances of 1000 meters is shown in Table A-5 as 0 dBi.

4.2.3 Surveying

In this operational scenario the separation distance of 1000 meters computed for the general use and assisted-GPS ground-based receivers is used, since the geometry can be the same.

For separation distances less than 1 kilometer, ITM defaults to the free space propagation model described in Equation A-3. Using free space propagation model the computed values of propagation loss used in this operational scenario for the 1000 meter separation distance are shown in Table A-5.

As shown in Table A-5, the reduction in the digital LPTV, translator, booster station antenna gain is –1.5 dB for a separation distance of 1000 meters.

In order to mitigate the effects of multipath, GPS receivers used for surveying applications will probably employ a choke ring antenna.[24] A general antenna pattern for a GPS choke ring antenna is provided in Table A-6.

Table A-6.

Off-Axis Angle (Measured with Respect to the Horizon)	GPS Antenna Gain (dBi)
$0 \leq 90\text{-}\theta \leq 80$ degrees	$7 - 1.957\text{x}10^{-3}\,(90\text{-}\theta)^{2.01}$
Otherwise	$21.59 - 0.3882(90\text{-}\theta) + 5.455\text{x}10^{-4}(90\text{-}\theta)^2$

The vertical angles are the complement of the angles shown in Table A-5 (90 – 1.6 = 88.4 degrees) for the 1000 meter separation distance. The GPS receive antenna gain using the model described in Table A-6 is –8.4 dBi for the 1000 meter separation distance.

4.3 Maritime GPS Receivers

4.3.1 Navigation in Constricted Waterways

In a previous analysis that examined interference to maritime GPS receivers, the United States Coast Guard indicated that the limiting operational scenario occurs when the GPS receiver is used for navigation in constricted waterways.[25] The previous analysis considered typical

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24. A choke ring antenna is designed to specificaly reduce multipath effects and consists of vertically aligned concentric rings centered about the antenna element connected to a ground plane. The vertical rings shape the antenna pattern such that multipath signals incident on the antenna at the horizon are attenuated.

25. NTIA Special Publication 01-45 at 3-10.

antenna heights of 13.5 meters and 7.5 meters for the GPS receiver antenna. The 13.5 meter antenna height is used in this analysis.

Similar to the ground-based GPS receiver analysis, the horizontal separation distance between the digital LPTV, translator, and booster station is computed based on the point where the coupling loss is a minimum value. To compute the coupling loss, the propagation loss is computed using Equation A-3. The antenna gain reduction for the digital LPTV, translator, and booster stations are provided in Table A-1. In order to mitigate the effects of multipath, maritime GPS receivers will typically employ a choke ring antenna, the pattern provided in Table A-6 is used in this analysis.

Table A-7 summarizes the coupling loss calculations for horizontal distances ranging from 200 meters to 1000 meters. In this operational scenario the separation distance of 400 meters is used as the minimum separation distance. Using free space propagation model in Equation A-3 the computed values of propagation loss used in this operational scenario for the 400 meter separation distance is shown in Table A-7.

As shown in Table A-7, the reduction in the digital LPTV, translator, booster station antenna gain is -6 dB for a separation distance of 400 meters.

As shown in Table A-7, the GPS receive antenna gain is –8.2 dBi for the 400 meter separation distance.

Table A-7.

Horizontal Separation Distance (m)	Slant Range (m)	Path Loss (dB)	Vertical Angle (degrees)	Reduction in TV Antenna Gain (dB)	Complement of Vertical Angle (degrees)	GPS Receive Antenna Gain (dBi)	Coupling Loss (dB)
200	200.7	82.5 (L1) 80.3 (L2) 80 (L5)	4.7	-13.8	85.3	-7.6	-103.9 (L1) -101.7 (L2) -101.4 (L5)
400	400.3	88.4 (L1) 86.2 (L2) 85.9 (L5)	2.4	-6	87.6	-8.2	-102.6 (L1) -100.4 (L2) -100.1 (L5)
800	800.2	94.5 (L1) 92.3 (L2) 92 (L5)	1.2	-0.7	88.8	-8.6	-103.8 (L1) -101.6 (L2) -101.3 (L5)
900	900.2	95.5 (L1) 93.3 (L2) 93 (L5)	1.1	-0.52	89.9	-8.6	-104.6 (L1) -102.4 (L2) -102.1 (L5)
1000	1000.1	96.4 (L1) 94.2 (L2) 93.9 (L5)	0.94	-0.3	89.1	-8.7	-105.4 (L1) -103.2 (L2) -102.9 (L5)

4.4 Operational Scenario Parameter Summary

A summary of the parameters for each of the operational scenarios considered in this analysis is shown in Table A-8. The summary includes the separation distance, the propagation loss, antenna gain reduction for the digital LPTV, translator, and booster stations, the GPS receive antenna gain, and any other scenario specific parameters such as applicable safety margin.

Table A-8.

Operational Scenario Parameters	Precision Approach	General Use	E-911	Surveying	Maritime Navigation
Horizontal Separation Distance (meters)	1500	1000	1000	1000	400
Propagation Loss (dB)	99.9 (L1) 97.4 (L5)	96.4 (L1) 94.3 (L2) 93.9 (L5)	96.4 (L1) 94.3 (L2) 93.9 (L5)	96.4 (L1) 94.3 (L2)	88.4 (L1) 86.2 (L2) 85.9 (L5)
TV Station Antenna Gain Reduction (dB)	-1.1	-1.5	-1.5	-1.5	-6
GPS Receive Antenna Gain (dBi)	-5	0	0	-8.4	-8.2
Aviation Safety Margin (dB)	6	0	0	0	0

5.0 ASSESSMENT OF COMPATIBILITY

In this section, the maximum allowable EIRPs for the UHF digital LPTV, translator, and booster stations are computed for each of the aviation, ground-based, and maritime GPS receiver operational scenarios identified in this analysis. The maximum allowable EIRP is computed using Equation A-2. The maximum permissible interference for the different GPS receiver architectures is given in Table A-2. The parameters for each operational scenario are given in Table A-8. The computed maximum allowable EIRP values are then compared to the levels permitted by the proposed Stringent Mask for UHF digital LPTV, translator, and booster stations in the Commission's NPRM. The difference between the computed and proposed EIRP values represents the available margin. If the computed value of maximum allowable EIRP is less than the value proposed by the Commission, a negative margin exists and additional attenuation below the proposed value is necessary to ensure compatible operation with aviation, ground-based, and maritime GPS receivers under the conditions specified in the operational scenarios.

5.1 Maximum Allowable EIRP Levels for UHF Digital LPTV, Translator, and Booster Stations

The EIRP levels for the UHF digital LPTV, translator, and booster stations in the RNSS frequency bands based on the proposed emission mask is –29 dBW/MHz for the Stringent Mask. The following tables show the computations for the maximum allowable emission mask for each of the aviation and ground-based GPS receiver operational scenarios considered in this assessment.

5.2.1 Aviation GPS Receivers

5.2.1.1 Precision Approach. Table A-9 shows the calculations of the maximum allowable EIRP based on the conditions specified in the aviation precision approach operational scenario. As shown in Table A-9, 14 dB of additional attenuation is required to ensure compatible operation.

Table A-9.

Parameters	L1	L5
I_{max} (dBW/MHz)	-140	-140
$G_T(\theta)$ (dB)	1.1	1.1
$G_R(\theta)$ (dBi)	5	5
L_P (dB)	99.9	97.4
L_{safety} (dB)	-6	-6
$EIRP_{max}$ (dBW/MHz)	-40	-42.5
$EIRP_{proposed}$ (dBW/MHz)	-29	-29
Margin (dB)	-11	-13.5

5.2.2 Ground-Based GPS Receivers

5.2.2.1 General Use. Table A-10 shows the calculations of the maximum allowable EIRP based on the conditions specified in the general use operational scenario. As shown in Table A-10, an additional 9 dB is required to ensure compatible operation.

Table A-10.

Parameters	L1	L2	L5
I_{max} (dBW/MHz)	-133.2	-133.2	-133.2
$G_T(\theta)$ (dB)	1.5	1.5	1.5
$G_R(\theta)$ (dBi)	0	0	0
L_P (dB)	96.4	94.3	93.9
$EIRP_{max}$ (dBW/MHz)	-35.3	-37.4	-37.8
$EIRP_{proposed}$ (dBw/MHz)	-29	-29	-29
Margin (dB)	-6.3	-8.4	-8.8

5.2.2.2 E-911. Table A-11 shows the calculations of the maximum allowable EIRP based on the conditions specified in the E-911 operational scenario. As shown in Table A-11, an additional 23 dB is required to ensure compatible operation.

Table A-11.

Parameters	L1	L2	L5
I_{max} (dBW/MHz)	-147	-147	-147
$G_T(\theta)$ (dB)	1.5	1.5	1.5
$G_R(\theta)$ (dBi)	0	0	0
L_P (dB)	96.4	94.3	93.9
$EIRP_{max}$ (dBW/MHz)	-49.1	-51.2	-51.6
$EIRP_{proposed}$ (dBw/MHz)	-29	-29	-29
Margin (dB)	-20.1	-22.2	-22.6

5.2.2.3 Surveying. Table A-12 shows the calculations of the maximum allowable EIRP based on the conditions specified in the surveying operational scenario. As shown in Table A-12, an additional 12 dB is required to ensure compatible operation.

Table A-12.

Parameters	L1	L2
I_{max} (dBW/MHz)	-145.5	-145.5
$G_T(\theta)$ (dB)	1.5	1.5
$G_R(90-\theta)$ (dBi)	8.4	8.4
L_P (dB)	96.4	94.3
$EIRP_{max}$ (dBW/MHz)	-39.2	-41.3
$EIRP_{proposed}$ (dBW/MHz)	-29	-29
Margin (dB)	-10.2	-12.3

5.2.3 Maritime GPS Receivers

5.2.3.1 Maritime Navigation. Table A-13 shows the calculations of the maximum allowable EIRP based on the conditions specified in the maritime navigation operational scenario. As shown in Table A-13, an additional 11 dB is required to ensure compatible operation.

Table A-13.

Parameters	L1	L2	L5
I_{max} (dBW/MHz)	-140	-140	-140
$G_T(\theta)$ (dB)	6	6	6
$G_R(\theta)$ (dBi)	8.2	8.2	8.2
L_P (dB)	88.4	86.2	85.9
$EIRP_{max}$ (dBW/MHz)	-37.4	-39.6	-39.9
$EIRP_{proposed}$ (dBw/MHz)	-29	-29	-29
Margin (dB)	-8.4	-10.6	-10.9

5.3 Summary of Analysis Results

The EIRP levels in the RNSS frequency bands for UHF digital LPTV, translator, and booster stations permitted is -29 dBW/MHz for the proposed Stringent Mask. Table A-14 provides a summary of the values of additional attenuation of the proposed EIRP levels that are necessary for compatible operation with aviation, ground-based, and maritime GPS receivers.

Table A-14.

GPS Receiver Operational Scenario	Additional Attenuation Below Proposed Emission Level (dB)
Precision Approach	14
General Use	9
E-911	23
Surveying	12
Maritime Navigation	11

As shown in Table A-14, an additional 23 dB of attenuation beyond the EIRP level proposed using the Stringent Mask is necessary to ensure compatible operation with receivers using assisted GPS technology under the conditions specified in each operational scenario. Based on the results of the analysis the maximum allowable EIRP level in the RNSS frequency bands for UHF digital LPTV, translator, and booster stations is –52 dBW/MHz.

6.0 CONCLUSIONS

Based on the results of the analysis the maximum allowable EIRP level in the RNSS frequency bands for UHF digital LPTV, translator, and booster stations is –52 dBW/MHz. This is a 23 dB reduction in the emission level permitted by the Commission's proposed Stringent Mask. The EIRP levels for the UHF digital LPTV, translator, and booster stations will apply across the entire 1559-1610 MHz, 1215-1240 MHz, and 1164-1215 MHz RNSS frequency bands.

ATTACHMENT B

ANALYSIS OF POTENTIAL INTERFERENCE FROM DIGITAL LOW POWER TELEVISION, TRANSLATOR, AND BOOSTER STATION PILOT CARRIER SIGNALS TO THE L1 GPS C/A CODE SIGNAL

Harmonic frequency interference is a special case of spurious emissions interference that occurs at integer multiples of the fundamental frequency of an interfering transmitter. The frequency of the harmonic emissions are given by:

$$F_{Harm} = n\, F_{Fund} \qquad \text{(B-1)}$$

where:

F_{Harm} is the frequency of the harmonic emission;
n is the harmonic number;
F_{Fund} is the fundamental frequency.

Global Positioning System (GPS) receivers using the L1 coarse/acquisition (C/A) code signal are known to be more susceptible to narrowband interference primarily because of the relatively short period of the C/A code.[1] With a period of 1 millisecond, the C/A code spectrum is not continuous, but rather it is a line spectrum with discrete lines at 1 kHz intervals. In addition, there are some "strong lines" in each C/A code that can deviate significantly from a $[\sin(x)/x]^2$ envelope.[2] This makes a C/A code receiver vulnerable to continuous wave (CW) or very narrowband interfering signals since they can mix with a strong C/A code line and affect the code and carrier tracking loops. The narrowband interference of concern is the power in a bandwidth less than 1 kHz.[3]

GPS receivers are also susceptible to wideband (e.g., noise-like) interference. The wideband interference of concern is the power in a 1 MHz bandwidth.

The emission spectrum of a typical digital television signal is shown in Figure B-1.[4]

1. RTCA DO-235, *Assessment of Radio Frequency Interference Relevant to the GNSS*, at C-4 (January 27, 1997) ("RTCA DO-235").

2. GPS receivers employing the longer P-code do not have this susceptibility to narrowband interfering signals, however, they have been shown to be more susceptible to wideband (e.g, noiselike) interfering signals.

3. It is not anticipated that the new civil signals at L2 and L5 will have a comparable susceptibilityto CW interference as is experienced by receivers using the L1 C/A code.

4. The Institute of Electrical and Electronics Engineers Transactions on Broadcasting, *DTV Repeater Emission Mask Analysis*, Volume 49, Number 1, at 35 (March 2003) ("IEEE Analysis").

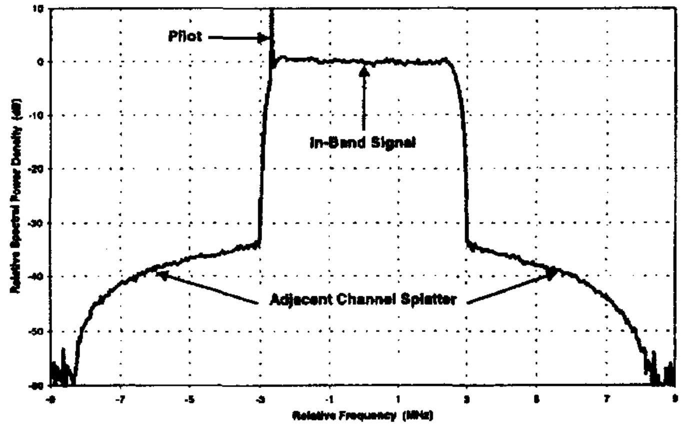

Figure B-1.

As shown in Figure B-1, the emission spectrum of the digital LPTV, TV translator, and booster signal will appear noise-like across the entire 6 MHz authorized channel, consistent with digital modulation techniques that are being employed. The exception is the narrowband pilot carrier signal that is located 309.441 kHz from the lower edge of the authorized channel.[5] Since the L1 C/A code receivers are so susceptible to narrowband interfering signals, an analysis of the potential interference for the digital low power television (LPTV), TV translator and TV booster station narrowband pilot carrier signal is necessary.

The digital TV spectrum shown in Figure B-1 is that as measured in a relatively narrow bandwidth. If the spectrum were measured in a 1 MHz bandwidth the pilot carrier signal would not be as evident. That is the pilot carrier signal (in a narrow bandwidth) is at best of comparable power to the noise-like portion of the spectrum measured in a 1 MHz bandwidth.[6] If the narrow band interference power is at least 10 dB below the wideband power, the wideband interference power will be the dominant interference effect.[7]

Table B-1 provides a list of the relationship between the very high frequency (VHF) and ultrahigh frequency (UHF) TV channels and the harmonic of the carriers that fall in the three portions of the radionavigation satellite service frequency bands that are used by GPS.

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5. IEEE Analysis at 34.

6. Jerry Whitaker, *DTV: The Revolution in Electronic Imaging*, McGraw-Hill (1998). Figures 9.7 and 9.8 show the digital TV spectrum measured in a 10 kHz resolution bandwidth and the pilot carrier signal is above the noiselike portion of the emission spectrum. However when the emission spectrum is measured in a 300 kHz resolution bandwidth the pilot carrier signal is of comparable amplitude to the noise-like portion of the emission spectrum.

7. RTCA DO-235 at Appendix G. For GPS C/A code receivers, the maximum permissible interference level for a narrowband interfering signal is 10 dB lower than that of a wideband interfering signal.

Table B-1.

Television Channel Number	Frequency Range (MHz)	Harmonic Number		
		1559-1610 MHz	1215-1240 MHz	1164-1188 MHz
22	518-524	3		
23	524-530	3		
24	530-536	3		
25	536-542	3		
32	578-584			2
33	584-590			2
34	590-596			2
36	602-608		2	
38	614-620		2	

In general as the harmonic number increases, the amplitude of the emission tends to decrease. The UHF channels, which are second and third harmonics of the fundamental of the TV channels, could be of sufficient amplitude to cause interference to the C/A code signal and are considered in this analysis.

For a harmonic signal generated from the fundamental of the UHF digital TV signal to interact with the spectral line of the C/A code, the signal must fall within the 1.023 MHz receiver bandwidth centered around the 1575.42 MHz GPS L1 center frequency. Harmonic signals that fall outside this bandwidth will not be of sufficient amplitude to interfere with the C/A code signal.[8] The narrowband pilot carrier signal is located 309.441 kHz from the lower edge of the authorized channel. So it will only be the harmonics of the pilot carrier signal that fall within the 1.023 MHz around the 1575.42 MHz GPS L1 center frequency, defined by 1574.9085 to 1575.9315 MHz, that could potentially interfere with the C/A code spectral lines. Table B-2 lists the TV channel, the frequency of the pilot carrier signal and the frequency of the third harmonic of the pilot carrier signal.

Table B-2.

Television Channel Number	Frequency of Pilot Carrier Signal	Frequency of Third Harmonic of the Pilot Carrier Signal
22	518.309 MHz	**1554.928 MHz**
23	524.309 MHz	**1572.928 MHz**
24	530.309 MHz	**1590.928 MHz**
25	536.309 MHz	**1608.928 MHz**

8. The C/A code has a $[\sin(x)/x]^2$ envelope. Beyond 1.023 MHz which defines the main lobe of the $[\sin(x)/x]^2$ signals will be attenuated by the following values: 13.5 dB (first side lobe), 17.8 dB (second side lobe), 20.3 dB (third side lobe), and 23 dB (fourth side lobe).

As shown in Table B-2, the third harmonic of the pilot carrier signals fall outside of the 1574.9085 to 1575.9315 MHz frequency, thus interference with the C/A code spectral lines will not occur. Rather the broad-band, noise-like interference of the digital LPTV, TV translator, and booster station emission is of primary concern.

ATTACHMENT C

PROTECTION OF RADIO QUIET ZONES, RADIO RECEIVING SITES, AND MONITORING STATIONS

In the Notice of Proposed Rulemaking, the Federal Communications Commission (Commission) proposes that digital low power television (LPTV), Class A, television (TV) translators, and booster stations conform to the requirements in Section 73.1030 of the Commission's Rules. The Commission also requests public comment on whether it might be appropriate to subject digital LPTV stations to these requirements only with regards to the more sensitive operations of the radio astronomy observatory Radio Quiet Zones (RQZs) at Green bank, West Virginia and Arecibo, Puerto Rico.[1]

The RQZs are regions of fixed-size, within which all transmissions are forbidden or where all transmissions need to be coordinated. These RQZs include radio astronomy and radio research installations that use sensitive receivers that can be very susceptible to interference. The Section 73.1030 limits are imposed on the field strength (and equivalent power flux densities) radiated onto the RQZs in the authorized bandwidth of the service, by any new or modified transmitting station. The field strength limits specified in Section 73.1030 of the Commission's Rules are the levels necessary to protect the sensitive receivers used on the RQZs, and are independent of the power levels of the transmitting station. Thus the field strength limit would be the same for full service digital TV stations as it would be for digital LPTV, translator, and booster stations.

The National Telecommunications and Information Administration (NTIA) Institute for Telecommunication Sciences (ITS) has maintained technical program oversight of the Table Mountain Radio Receiving Zone to assure the levels of unwanted radio frequency energy within the site conforms with federal regulations and to ensure that users do not interfere with each other.[2] This oversight allows research concerned with low signal levels such as calibration and testing of sensitive receivers and other sensor systems, weak satellite signals, precise measurements of the spectrum, antennas, and background noise to be conducted under near ideal conditions not to be found in most areas of the United States. The Table Mountain facility is absolutely essential to research in the areas of very wideband receiver technology and radio wave propagation. ITS has a number of permanent facilities used for ongoing research projects at Table Mountain. In addition to ITS, the facilities at Table Mountain support research and

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1. *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television, Television Translator, and Television Booster Stations and to Amend Rules for Digital Class A Television Stations*, Notice of Proposed Rulemaking, MB Docket No. 03-185, 68 Fed. Reg. 55566, at ¶ 60 (2003).

2. National Telecommunications and Information Administration, Institute for Telecommunication Sciences, NTIA Technical Memorandum TM-03-45, *Digital Television (DTV) Field Strength and Video Quality Study* (August 2003) available at http://its.bldrdoc.gov/pub/ntia-rpt/03-405/; National Telecommunications and Information Administration, Institute for Telecommunication Sciences, NTIA Report 01-387, *Predicted and Measured Field Strengths in the Boulder, Colorado, Area from Two Proposed Terrestrial Digital Television Tower Sites* (May 2001) available at http://its.bldrdoc.gov/pub/ntia-rpt/01-387/.

development activities being performed by the National Institute of Standards and Technology, the National Oceanic and Atmospheric Administration, the United States Geological Survey, as well as other federal agencies, research universities, and telecommunications and technology industries.

Section 73.686 of the Commission's Rules provide specific procedures for measuring field strength for an analog TV signal. However, these procedures are not used for determination of compliance with the regulations that protect RQZs. In fact, the results of these procedures are approximate since only the video carrier of the analog TV signal is measured. Unlike analog TV signals, TV signals that employ digital modulation do not have a distinct carrier. The correct procedure to determine compliance of a digital LPTV, translator, and booster station is to measure the electric field strength in the full authorized bandwidth of 6 MHz, as required in Section 73.1030 of the Commission's Rules.

NTIA supports the Commission's proposal that digital LPTV, translators, and booster stations conform to the requirements in Section 73.1030. These limits apply to the total power radiated by a digital LPTV, translator, and booster station, which is the appropriate means of protecting sensitive wideband measurements. Given the importance of the measurements performed by the Department of Commerce radio receiving facility at Table Mountain, Colorado, NTIA believes that the field strength limits and coordination requirements specified in Section 73.1030 of the Commission's Rules must apply to digital LPTV, translator, and booster stations operating in proximity to this facility.